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16. ABSTRACT
Mysids, small shrimp-like crustacea, are used as practical bioassay animals for investigating the effects of cadmium in seawater. In laboratory tests, the mysid (Mysidopsis bahia)was more sensitive to cadmium than other crustaceans tested. LC50 values were 15.5 µg/l within 96 hours and 11.3 µg/l during a 17-day life cycle; LC50's for other selected crustaceans were between 120 and 720 µg/l. Results of life-cycle bioassays with mysids can aid in establishing water quality criteria for marine and estuarine organisms.

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The Acute and Chronic Effects of Cadmium on the Estuarine Mysid, *Mysidopsis bahia*

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INTRODUCTION

Determining the lethal effects of a pollutant on animals is easier than finding the concentration which decreases an animal's life span, growth, reproduction, or movements. Consequently, biologists have emphasized the short-term "lethal effects" of environmental factors on single life stages (usually adult) even though the long-term sublethal effects of all life stages have greater ecological implication (WARREN, 1971). For example, effects of a pollutant can differ during life stages of the same species: A concentration of 1.0 µg/ℓ polychlorinated biphenyl, killed 50% of juvenile pink shrimp, Penaeus duorarum, in 15 days, whereas 3.5 µg/ℓ was toxic to 50% adult shrimp in 35 days (NIMMO et al., 1971).

We have found a species of crustacea which is capable of completing a life cycle in a few days; therefore, we can assess effects of a pollutant in all life stages. This species is a shrimp-like crustacean called a mysid. Commonly referred to as "opossum shrimp" because the female carries the young in a brood pouch during development, mysids are an important element of estuarine plankton and therefore are integral in estuarine and marine food webs (SCINTILA DE ALMEIDA PRADO, 1973). The species, Mysidopsis bahia (MOLENOCK, 1969), was first described from West Bay, Galveston, Texas, and also occurs in South Florida (BRATTEGARD, 1970).

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Previous research has demonstrated that life-cycle bioassays can be used to establish the maximum concentration an organism can tolerate before discernible damage (EATON, 1973). These bioassays, often called "chronic tests," must be conducted in flow-through aquaria to minimize problems of anoxia, loss of toxicant to container walls, buildup of metabolic products, and growth of microorganisms (BAHNER et al., 1975). Flow-through rather than static tests more accurately simulate situations that aquatic species may encounter in the environment (ANONYMOUS, 1975), and therefore, flow-through tests are superior for identifying detrimental effects which relate to enforcement decisions concerning quality of water (WUERTHELE et al., 1973). To our knowledge, the only report on effects of a toxicant in the life cycle of an estuarine or marine species concerned the sheepshead minnow, Cyprinodon variegatus (SCHIMMEL and HANSEN, 1974). Some reasons for the lack of such bioassays may be the time required for many fishes, crustaceans, and mollusks to complete a life cycle; high cost of maintaining satisfactory environmental factors; and lack of information on the nutritional requirements of larval stages.

The need to conduct longer-term bioassays was demonstrated in research on the brown shrimp, Crangon crangon, during which the 1500-hour LC50 (concentration at which 50% of the animals died) for cadmium was 1/100th that of the 48-hour LC50 (WILSON and CONNER, 1971). However, "Water Quality Criteria, 1972," (1973) reported that only 12% of 332 experiments with estuarine animals were flow-through tests that lasted longer than 96 hours. No tests were conducted on entire life cycles of any estuarine or marine species.

METHODS

In our experiments, mysids were cultured in a 40-liter glass aquarium supplied with filtered, flowing water (15 to 25% salinity) at 25-28° and were fed 48-hour-old Artemia salina larvae. Overflow was through a standpipe to which a ring of Nitex® screen was attached to prevent young mysids and Artemia from escaping.

Mysids were exposed to four concentrations of cadmium and a control without cadmium. One liter of water with cadmium as $CdCl_2$ was delivered every five minutes to each 5-ℓ aquarium in an intermittent flow from a diluter (MOUNT and BRUNGS, 1967). As the volume was attained in each of the five aquaria within 25 minutes,

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a self-starting siphon drained the water to a volume of one liter. The fluctuating levels insured an exchange of water within each aquarium and the small chambers devised to retain the mysids. The chambers consisted of a standard glass Petri dish to which a 15-cm high cylinder of Nitex screen (mesh number 210) was cemented. To begin each test, twenty 24-hr juveniles, five animals per chamber, were exposed to each concentration. A small stream of compressed air was delivered into each chamber as a precaution against possible anoxic conditions. In recording daily changes in populations, each chamber was gently lifted from the aquarium; water was drained through the Nitex cylinder to the level of the Petri dish, which was then placed on a lighted counter top. Numbers of live animals by sex, number of females with and without brood pouches, and numbers of young were recorded.

To find the concentrations of cadmium to be used in an entire life-cycle bioassay, we conducted a 96-hour test beginning with 24-hr old juvenile mysids. Concentrations, measured by atomic absorption spectroscopy (NIMMO et al., in press), were control, 5.09, 8.1, 14.2 and 31.9 µg/ℓ. The second test involved a 23-day life cycle with measured concentrations of control, 4.8, 6.4, 10.6 and 28.0 µg/ℓ.

RESULTS AND DISCUSSION

Table 1 summarizes the toxicity of cadmium in the mysid life-cycle bioassay. The LC50 calculated by probit analysis (FINNEY, 1971) using measured concentrations was 15.5 µg/ℓ (95% F.L. 12.6-19.6) in the 96-hour test and 11.3 µg/ℓ (95% F.L. 4.2-12.9) in the 17-day exposure. The life cycle was 17 days, the period during which the females in

TABLE 1

Survival of *Mysidopsis bahia* in various concentrations $CdCl_2$ in seawater

Days	Cd, µg/ℓ				
	Control	4.8	6.4	10.6	28.0
0	20	20	21	20	20
11	19*	19*	16	16*	1
13	19	19	16*	16	0
17	19**	19**	16	13	0
18	19	19	16**	11	0
20	19	19	16	8**	0
23	19	19	16	2	0

*Formation of brood pouches noted in the chambers.
**Young released. Average number of young/female at 23 days was 7.0 in control, 8 in 4.8 µg/ℓ, 3 in 6.4 µg/ℓ and 4 in 10.6 µg/ℓ. Temperature range, 20-28°; salinity, 15-23 °/oo.

the control aquarium released the brood (Table 1). These data can be compared with LC50's reported (EISLER, 1971) for other crustaceans that are relatively more sensitive to cadmium than echinoderms, annelids, mollusks, or fishes (Table 2).

TABLE 2

LC50 concentrations of cadmium (µg/ℓ) lethal to 50% of test animals within 96 hours (EISLER, 1971)

Species	Cd, µg/ℓ
Hermit crab, Pagurus longicarpus	320
Sand shrimp, Crangon septemspinosa	320
Common starfish, Asterias forbesi	820
Common soft-shell clam, Mya arenaria	2,200
Green crab, Carcinus maenus	4,100
Atlantic oyster drill, Urosalpinx cinerea	6,600
Eastern mud snail, Nassarius obsoletus	10,500
Sandworm, Nereis virens	11,000
Striped killifish, Fundulus majalis	21,000
Blue mussel, Mytilus edulis	25,000
Sheepshead minnow, Cyprinodon variegatus	50,000
Mummichog, Fu. dulus heteroclitus	55,000

For example, after 96 hours the LC50 for sand shrimp, Crangon septemspinosa, and hermit crab, Pagurus longicarpus, was 320 µg/ℓ (EISLER, 1971). By comparison, the 30-day LC50, conducted in flowing water bioassays with pink shrimp, Penaeus duorarum, was 720 µg/ℓ, and in a similar experiment, the 29-day LC50 for grass shrimp, Palaemonetes vulgaris, was 120 µg/ℓ (NIMMO et al., in press). Thus the sensitivity of the mysid, M. bahia to cadmium, was greater than that reported for any other animal. In addition to mortality data, we observed a 24-hour delay in the formation of brood pouches of females exposed to 6.4 µg/ℓ. We believe, however, the 72-hour delay in release of brood by females in the 10.6 µg/ℓ (Table 1) was a deleterious effect. Fewer young were produced by all females in the 6.4 and 10.6 µg/ℓ aquaria than by females in the control and the 4.8 µg/ℓ Cd aquaria.

Mysidopsis bahia has exhibited its suitability as an organism for long-term bioassays through these characteristics: ease of maintenance in the laboratory, shortness of life cycle (a saving in time and resources), capacity to produce information in addition to mortality, and sensitivity to a known toxicant. Results of such studies can aid in establishment of water quality criteria for marine and estuarine biota and in development of guidelines for ocean-dumping or pesticide usage.

SUMMARY

Mysids, small shrimp-like crustacea, proved to be a practical bioassay animal for investigating the effects of cadmium in seawater and may serve this purpose for other pollutants. In the laboratory under flow-through test conditions, the mysid, Mysidopsis bahia, was more sensitive to cadmium than other crustaceans tested. LC50 values were 15.5 µg/ℓ within 96 hrs and 11.3 µg/ℓ during a 17-day life cycle, whereas LC50's for other selected crustaceans were between 120 and 720 µg/ℓ. Results of life-cycle bioassays can aid in the establishment of water quality criteria for marine and estuarine organisms.

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